Towards Modernizing the Electrical Grid

The Real-Time Middleware Experts

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Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
MAY 2011		**00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Towards Modernizing the Electrical Grid	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Real-Time Innovations, Inc (RTI),232 E. Java Drive,Sunnyvale,CA,94089**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

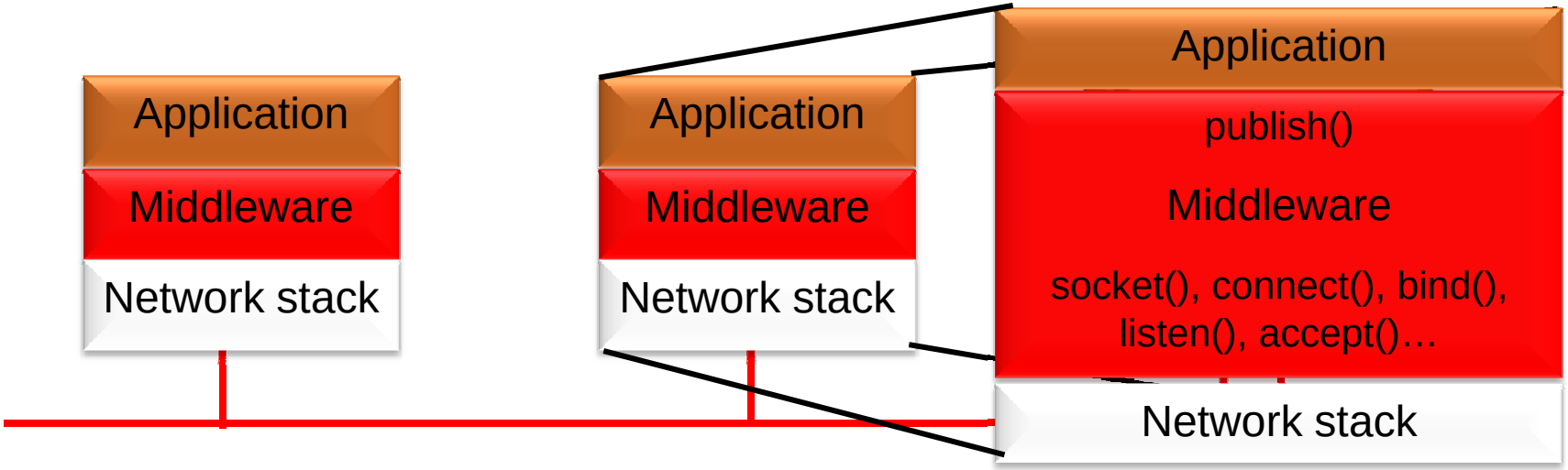
13. SUPPLEMENTARY NOTES
Presented at the 23rd Systems and Software Technology Conference (SSTC), 16-19 May 2011, Salt Lake City, UT. Sponsored in part by the USAF. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**35**	

What & Why is Middleware?



- What?
  - Middleware is a layer between application and network stack
  - It presents a more powerful API to the application
  - It handles connections, failures, changes
- Why?
  - Simpler conceptual model
  - Easier programming
  - Seamless interoperability
  - Control communications "Quality of Service" (QoS)

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Why Not Use TCP? (or C37.118)

- Rigid reliability protocol
- No multicast
- No OOB data
- Only global timeouts
- Can't do real time, can't filter
- Does not scale
- No prioritization
- Can't handle varying delivery QoS needs

Not intended for mission-critical real time

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Why Not Use UDP?

- No reliability
- No discovery (where's the data?)
- No queuing or buffering
- No loss detection
- Must keep track of who needs the data
- Inefficient use of network resources

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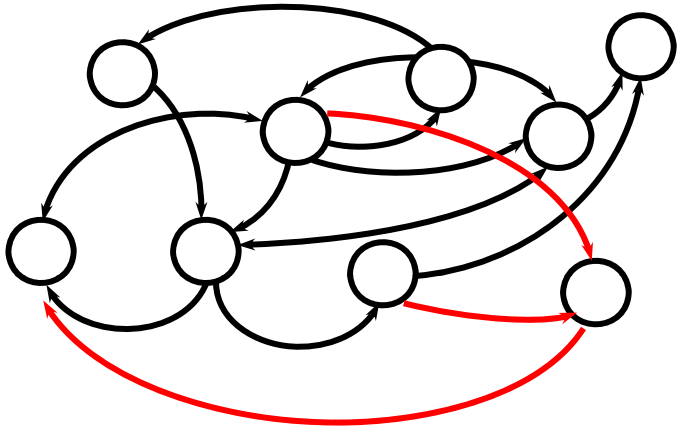
Data-Centric Decoupling

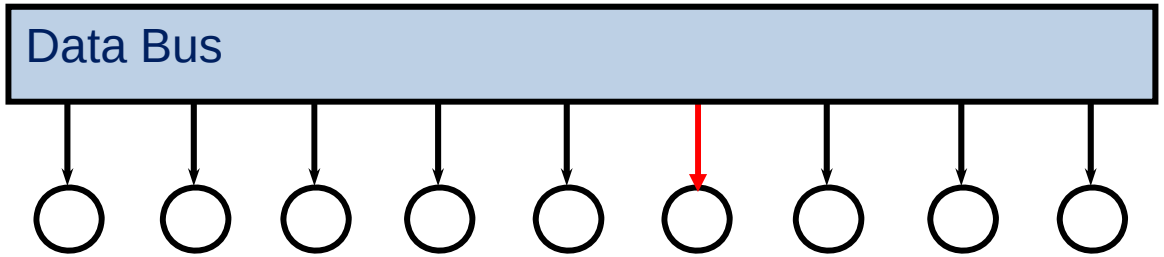
Connection-oriented

- Hard-wired
- Multi-hop
- Brittle
- Hard to evolve



Data-centric

- Loosely coupled
- Peer-to-peer
- Scalable
- Evolvable



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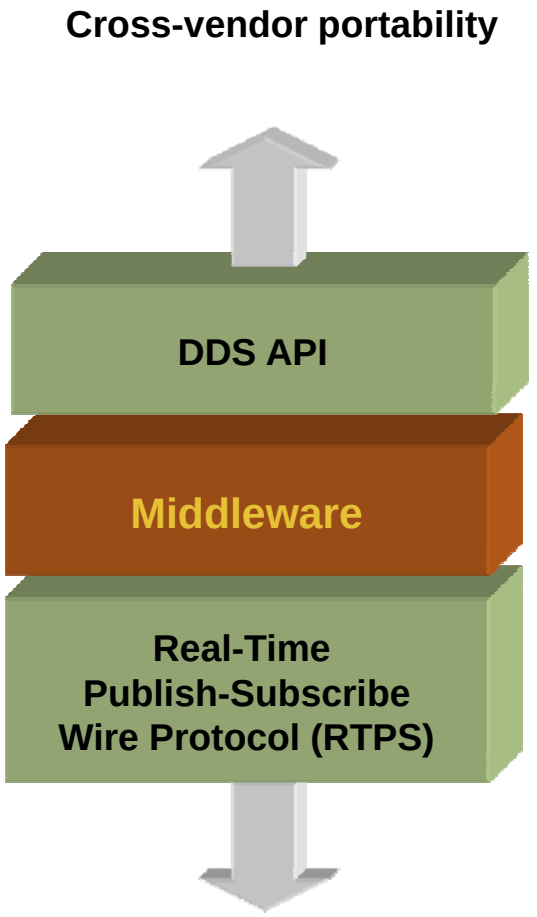
The DDS Standard

- OMG Data Distribution Service for Real-Time Systems
  - Data-centric pub-sub
  - Per-channel QoS
    - Right data to the right place at the right time
  - Content and time aware
- No vendor lock-in
  - API for source portability
  - Message encoding for interoperability
- Transparent connectivity
  - C, C++, Java, .NET (C#, C++/CLI)
  - Windows, Linux, Unix, embedded, real-time



RTPS also standardized as IEC 61148

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DDS Adoption

- Multiple vendors
  - 9 implementations!
- Dominant in military
  - DISA: DISR mandated
  - Navy: Open Architecture, FORCEnet
  - Air Force, Navy and DISA: NESI
  - Army: FCS / SoSCOE
  - NATO, South Korea, many more
- Many other applications
  - Air traffic control, industrial automation, transportation, medical
- Hundreds of active programs

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What Does DDS Do?

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Ship Self-Defense System

The Ship Self Defense System is the “last line of defense”

SSDS coordinates high-speed radars, targets defensive missiles, and directs 1000+ rounds/sec at incoming cruise missiles

SSDS is in sea trial now

DDS *reliably delivers messages in real time*

Flight Simulation

"In the past we probably would have developed an expensive, proprietary system for data communications. By using RTI, we were able to deliver a proven, reliable and cost effective solution to our customers."

--Peter Jarvis, Chief Designer

CAE, one of the world's leading providers of simulation and training, uses RTI over high-bandwidth IEEE-1394 on its Sim XXI product line.

Middleware provides transport portability and architecture interoperability

Air Traffic Management

- Air traffic control flow traffic through busy metropolitan air spaces
- Reliability is critical – hardware or software failures mean flight delays and substantial costs
- Without disrupting the data flow, RTI permits fast addition, updating and removal of system nodes

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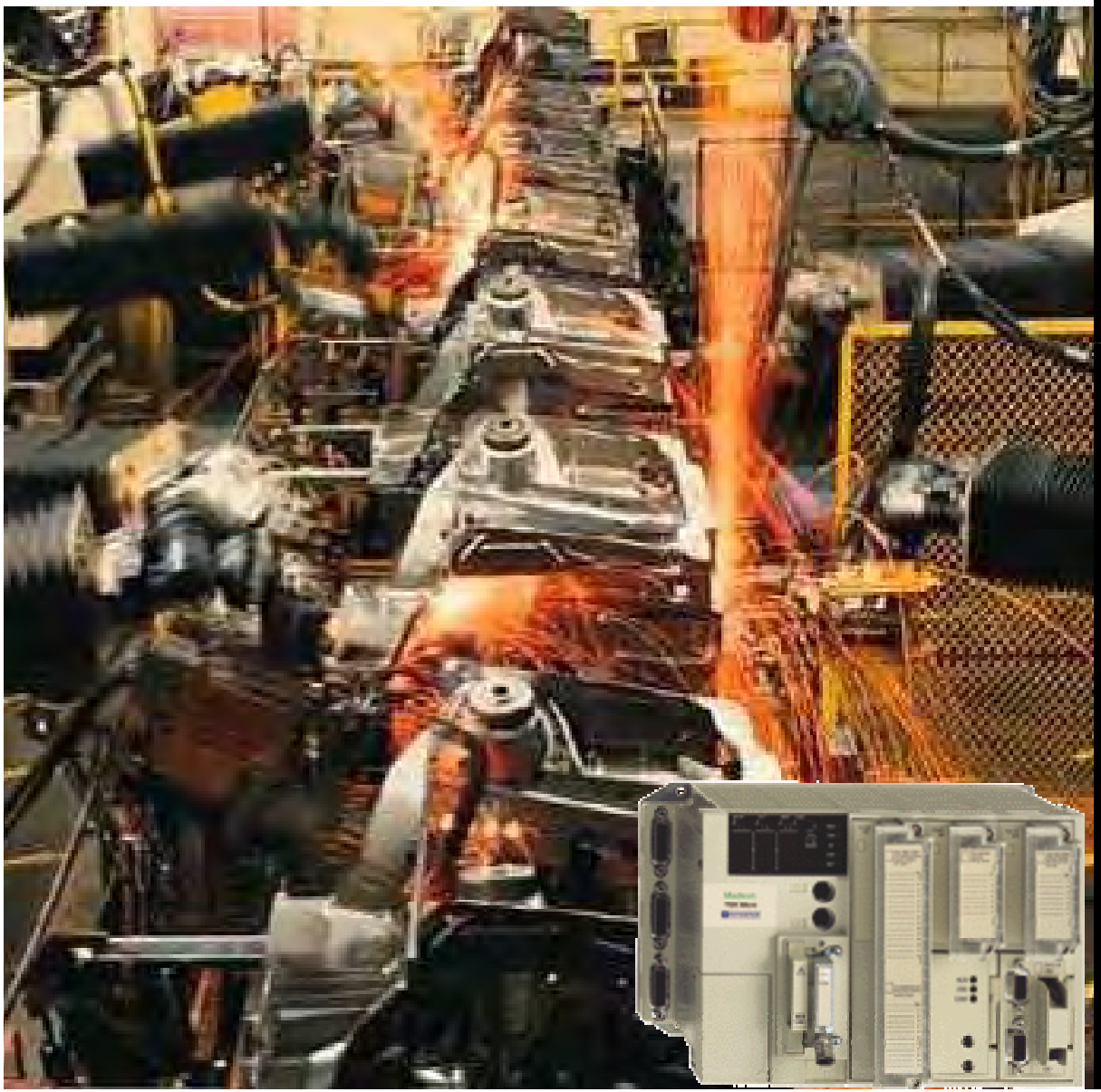
Schneider PLCs



- Global discrete manufacturer of factory automation equipment
- Modern factories require up-to-the-minute data, even with limited memory and processing power
- Standardized protocol IEC 61148

- DDS middleware controls large SCADA systems

Cancer Treatment

Still Rivers's PBRT (Proton Beam Radiation Therapy) system zaps tumors with accelerated protons.

The treatment must be continuous for 30-40 days; downtime endangers treatment success.

Still River built the world's smallest, reliable, autonomous, turn-key, therapist-operated PBRT system in record time

Automotive Safety

The VW Driver Assistance & Integrated Safety system provides steering assistance when swerving to avoid obstacles, detects when the lane narrows or passing wide loads, and helps drivers to safely negotiate bends.

Middleware *bridges high speed networking to the CAN bus*

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Human Robotic Systems

NASA's Human-Robotic Systems Project is building four prototype robots that will someday operate on extraterrestrial surfaces.

The project coordinates four NASA centers building four different robots. They operate in realistic environments, including over low-bandwidth, high-delay, lossy communications.

DDS middleware allows these very different systems to share a common data communications over disadvantaged links

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How Does DDS Work?

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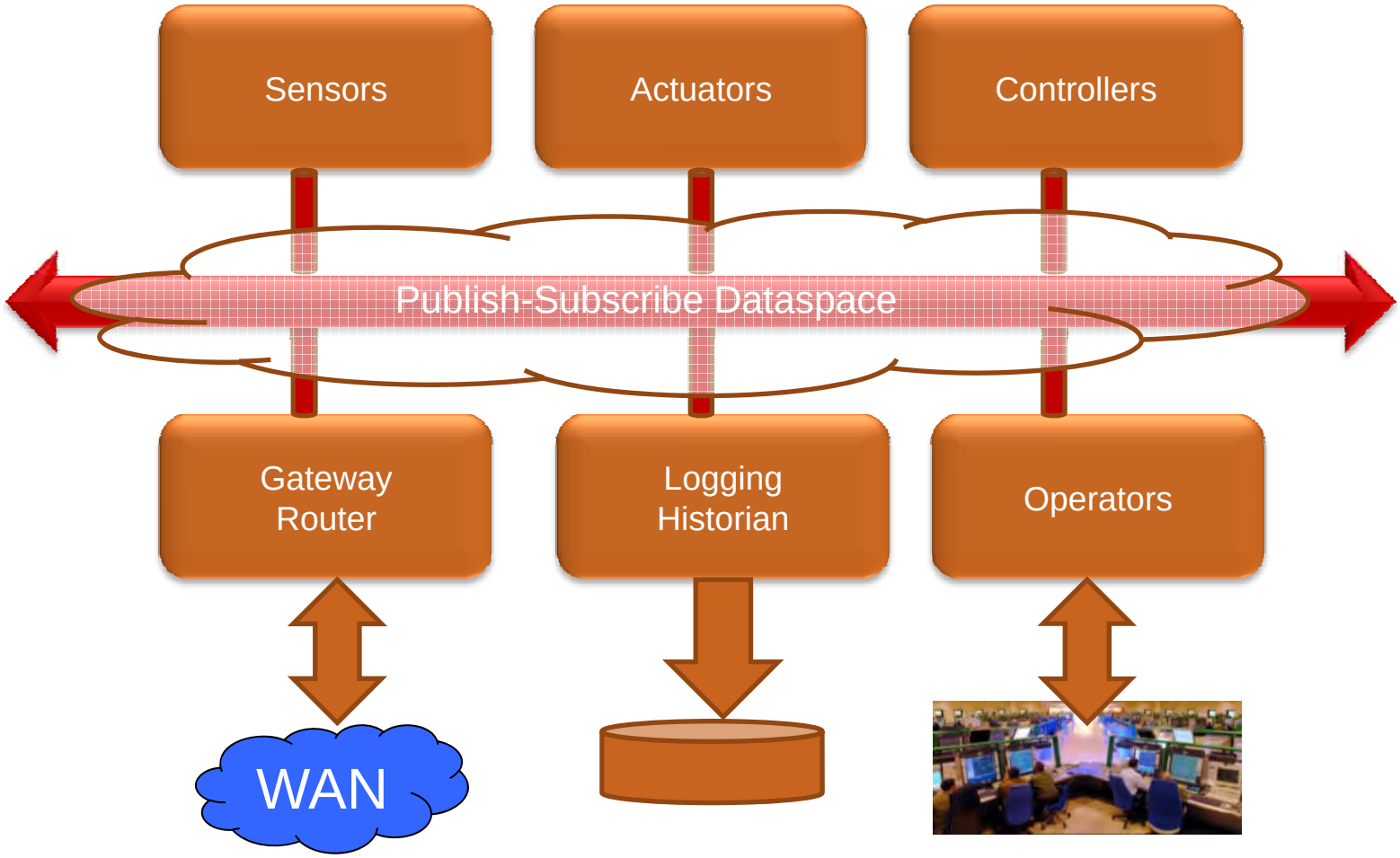
Real-Time Integration Infrastructure



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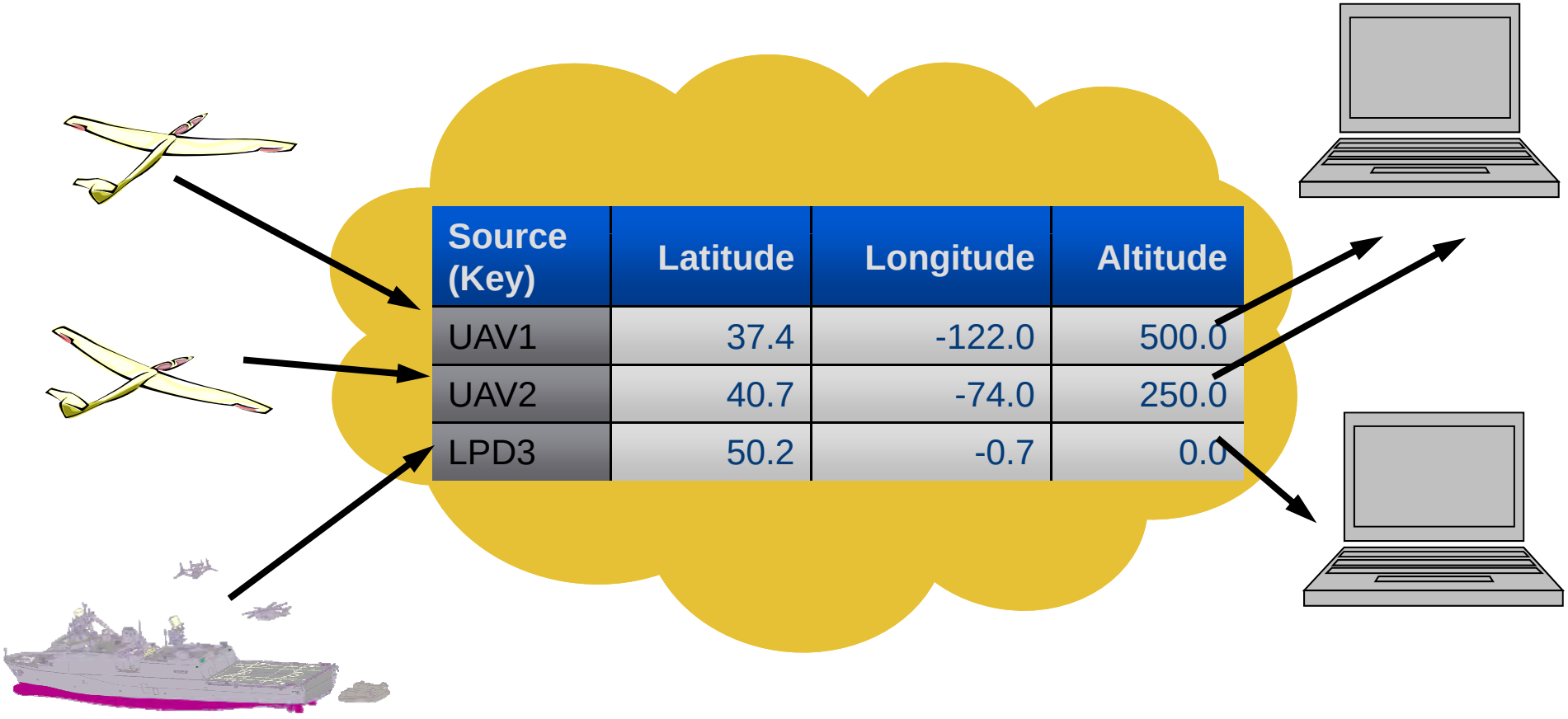
DDS “Global Data Space”



Source (Key)	Latitude	Longitude	Altitude
UAV1	37.4	-122.0	500.0
UAV2	40.7	-74.0	250.0
LPD3	50.2	-0.7	0.0

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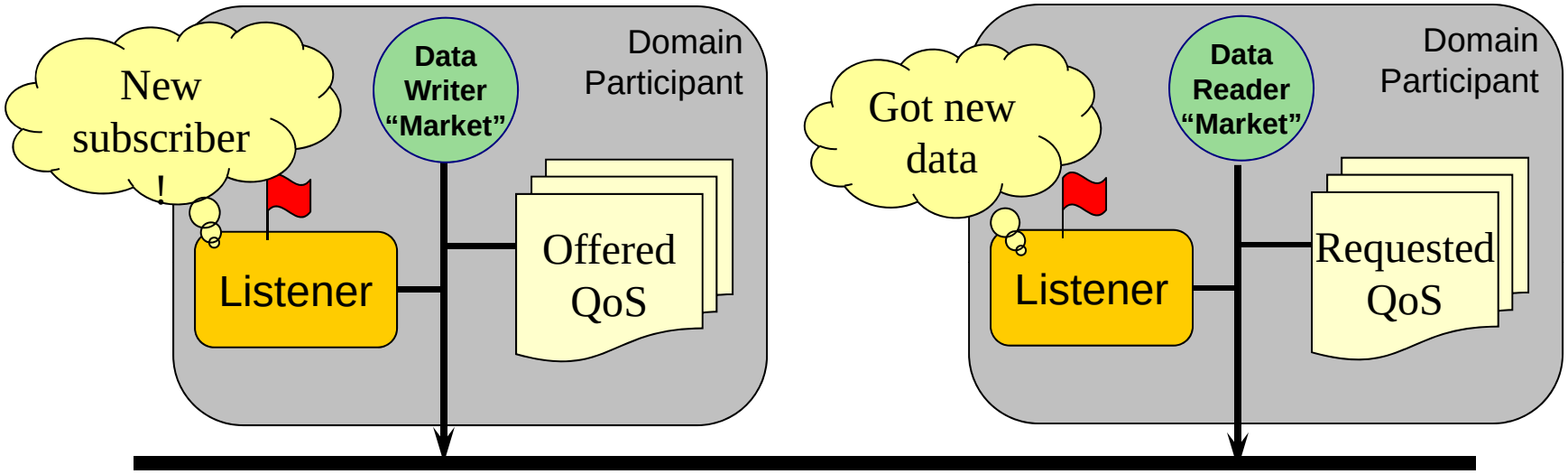
DDS communications model



- Typed, topic-based subscriptions ensure correct, easy communications
- QoS Contracts control information flow
  - Reliability, filtering, liveliness, resources
- Real-time notification provides deterministic behavior

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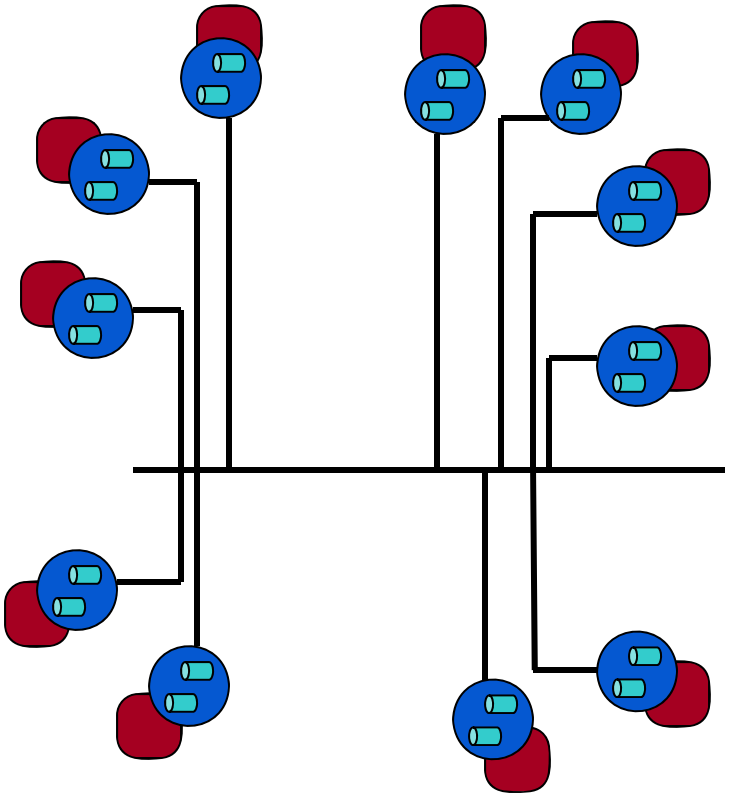
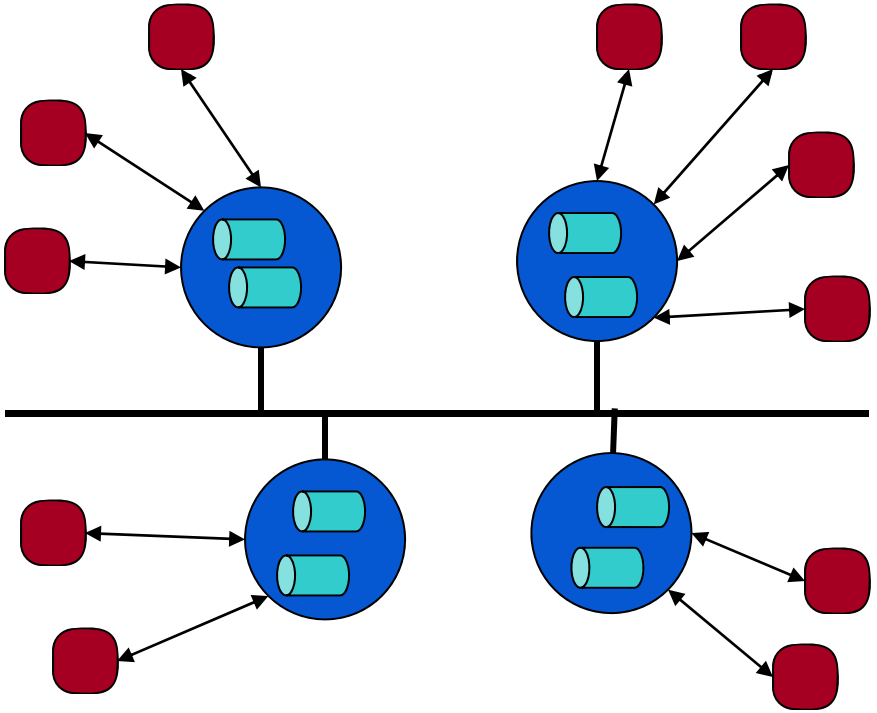
Peer-to-Peer Efficiency

Peer-to-Peer



Broker-based



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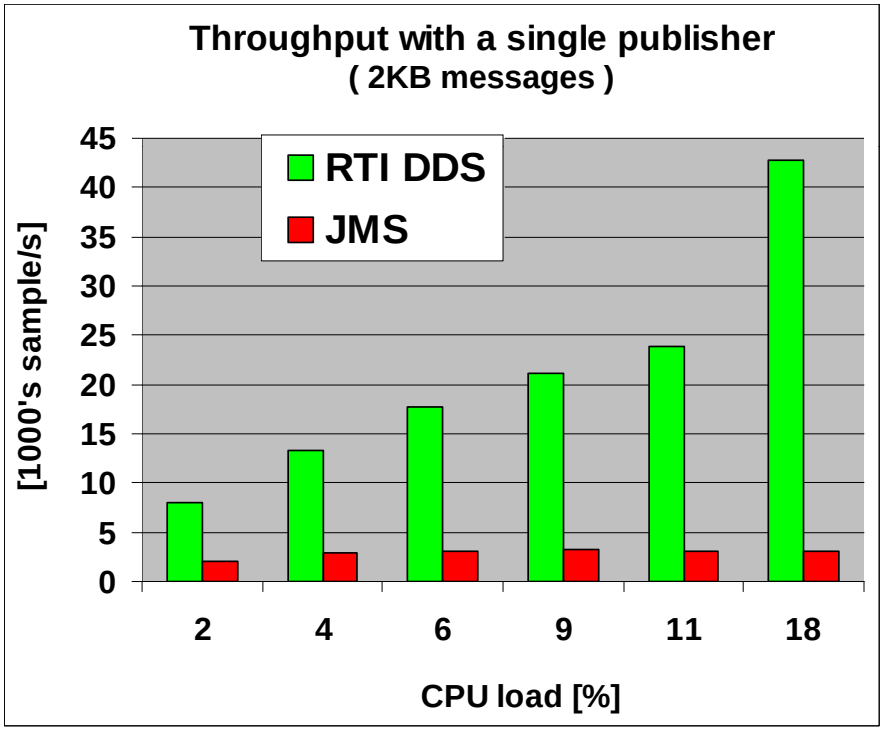
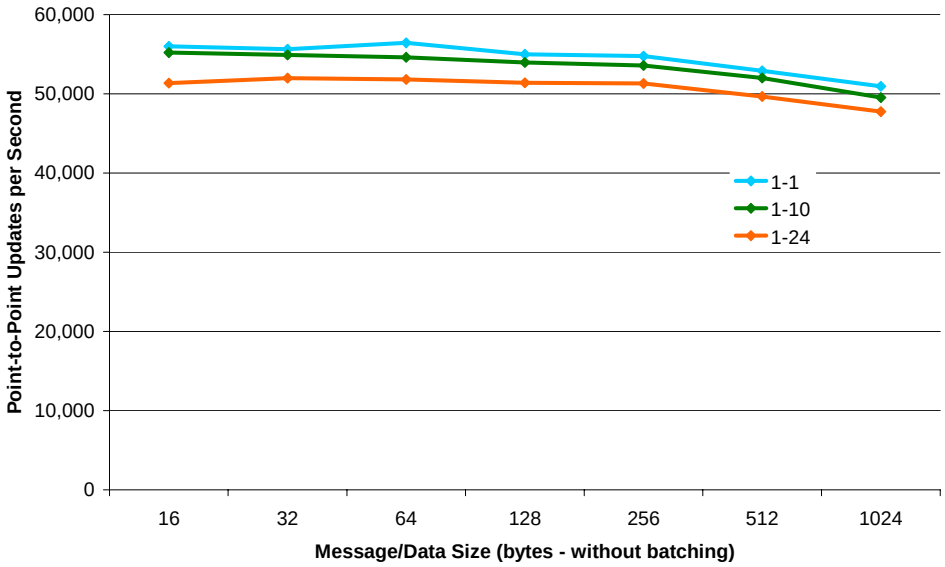
Fast & Scalable

DDS is ~20X faster than JMS





DDS reliable multicast exhibits nearly perfect scalability

Platform: Linux 2.6 on AMD Athlon, Dual core, 2.2 GHz

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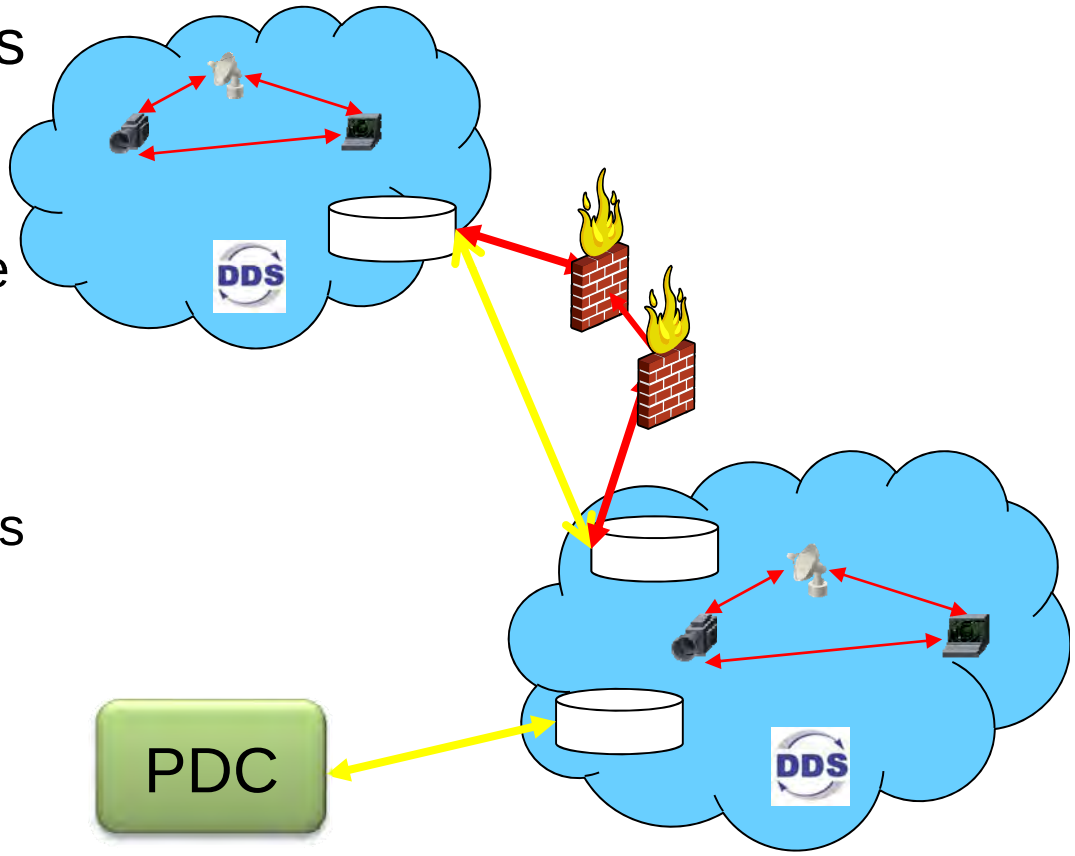
Extend DDS for Multiple Systems

- Routing service connects DDS domains
  - Filters (guards)
  - Translates
  - A programmable bridge
- Decouples development
  - Can span DDS domains
    - Different types, topics, versions
  - Can span WAN
  - Can span other protocols



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DDS in the Grid…

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To create a robust, widely available and secure measurement infrastructure for the interconnected North American electric power system

- WECC
- NYISO
- Midwest ISO
- PJM
- Southern Cal Edison
- ISO New England
- CCET
- EPRI
- Bonneville Power Administration
- Grid Protection Allience
- Washington State University
- University of Illinois
- UC–Berkeley
- Georgia Institute of Technology
- Virginia Tech

- IncSys
- Areva
- OSISoft
- RTI
- Qualitrol
- Power World
- Space Time Insight
- Ametek
- TLI Inc
- Schweitzer Engineering Laboratories
- Siemens
- Psymetrix
- General Electric
- Verizon
- Many more

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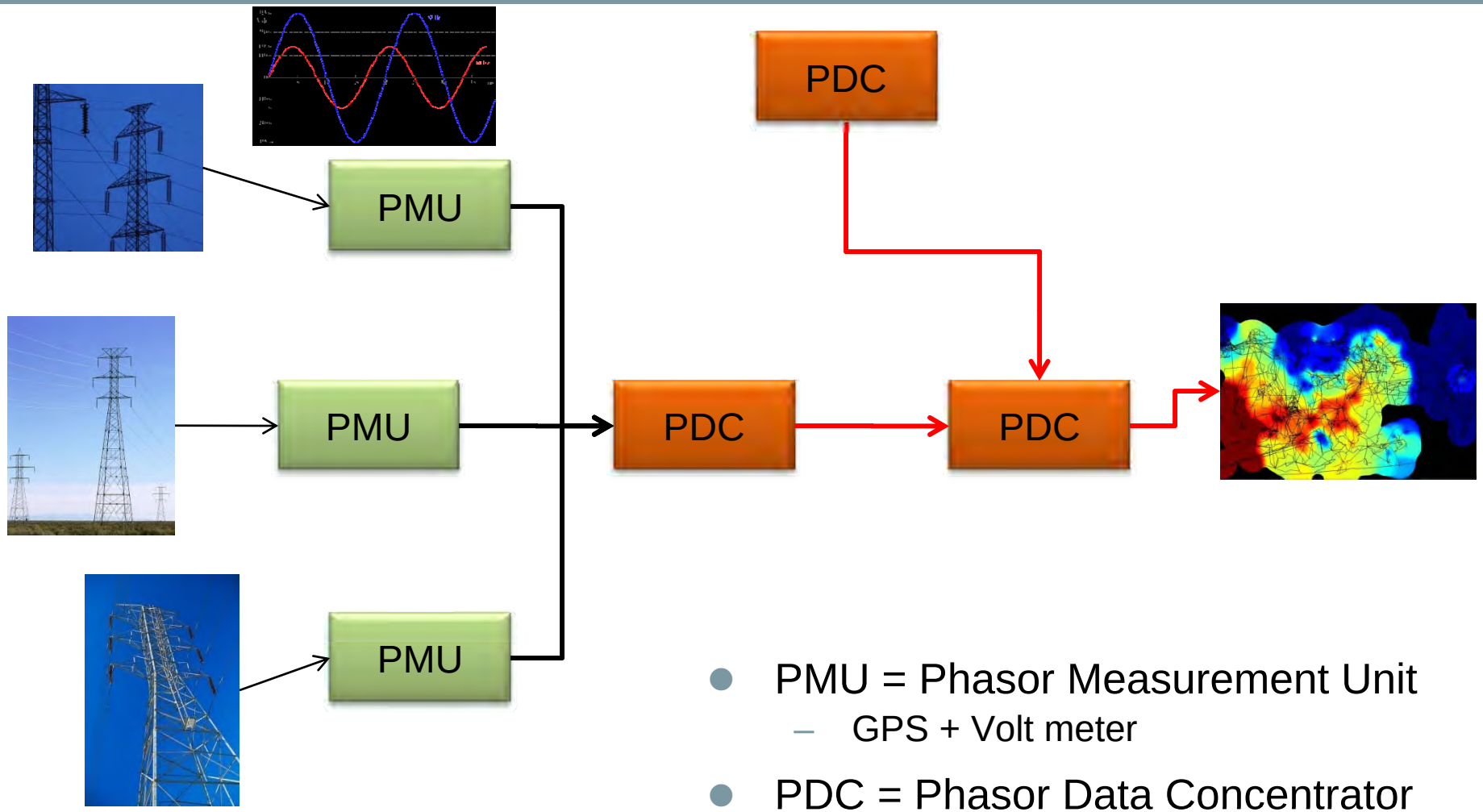
Synchro Phasors



- PMU = Phasor Measurement Unit
  - GPS + Volt meter
- PDC = Phasor Data Concentrator
  - Collates PMU measurements

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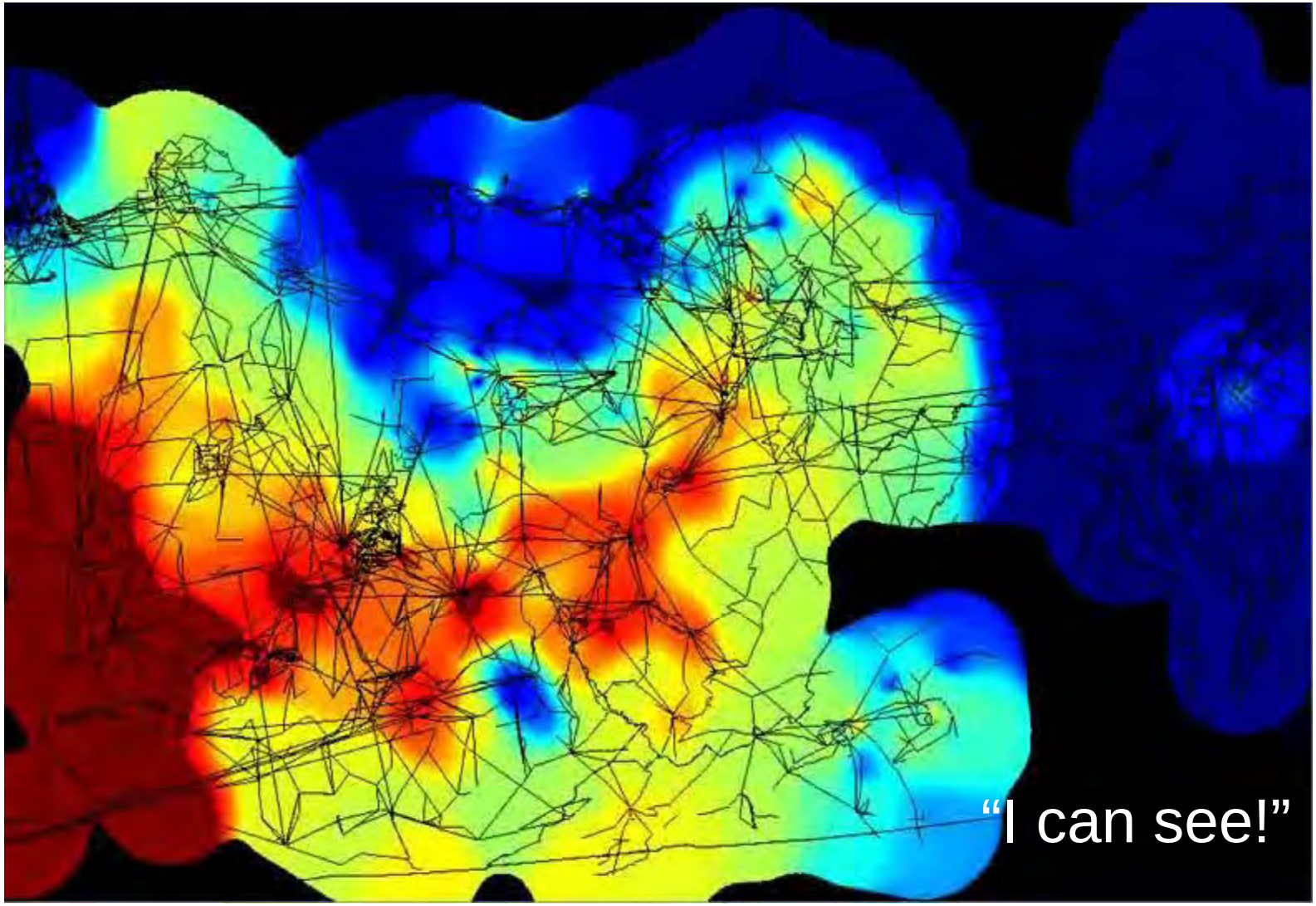
Synchro Phasors



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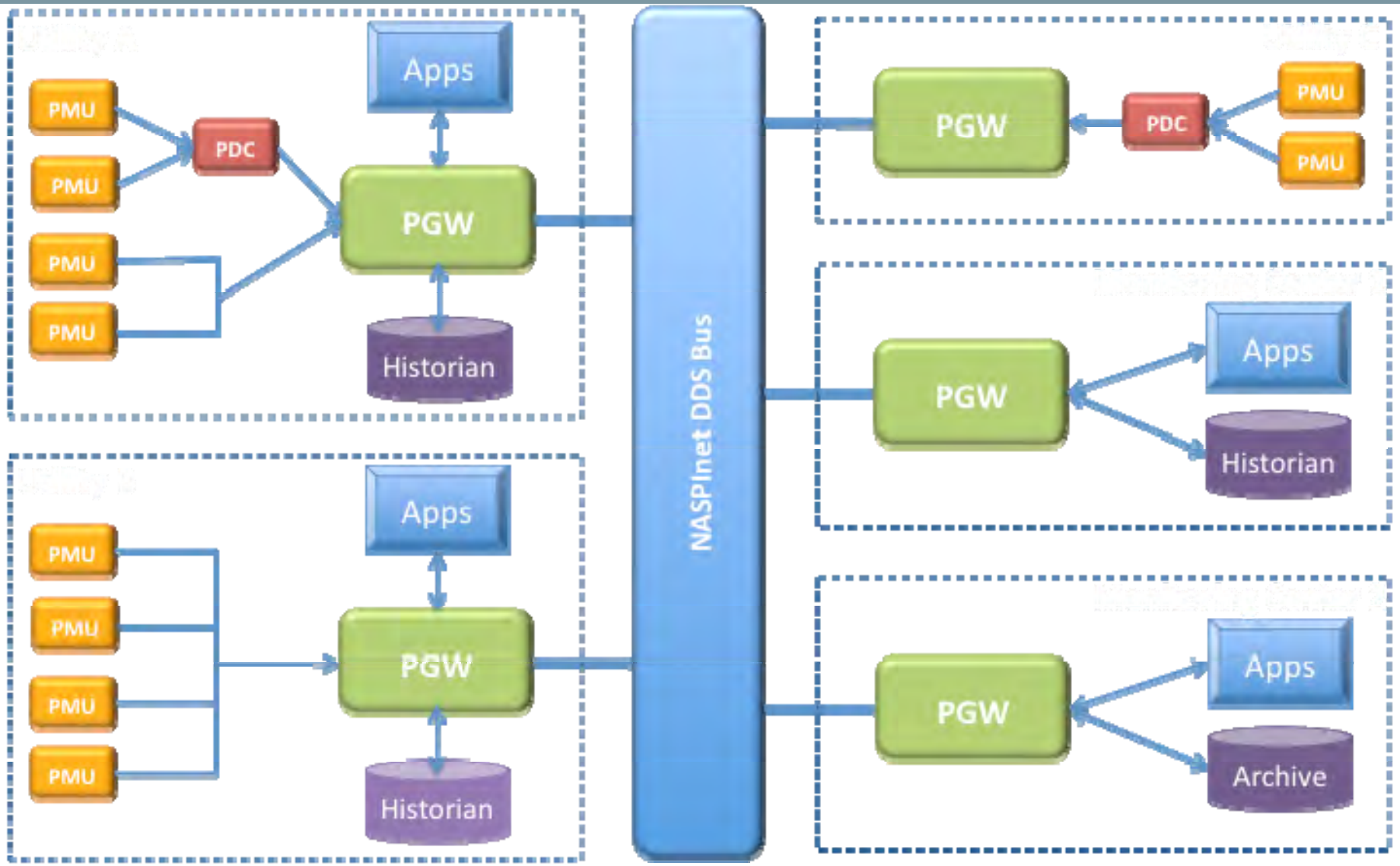
NASPInet Architecture



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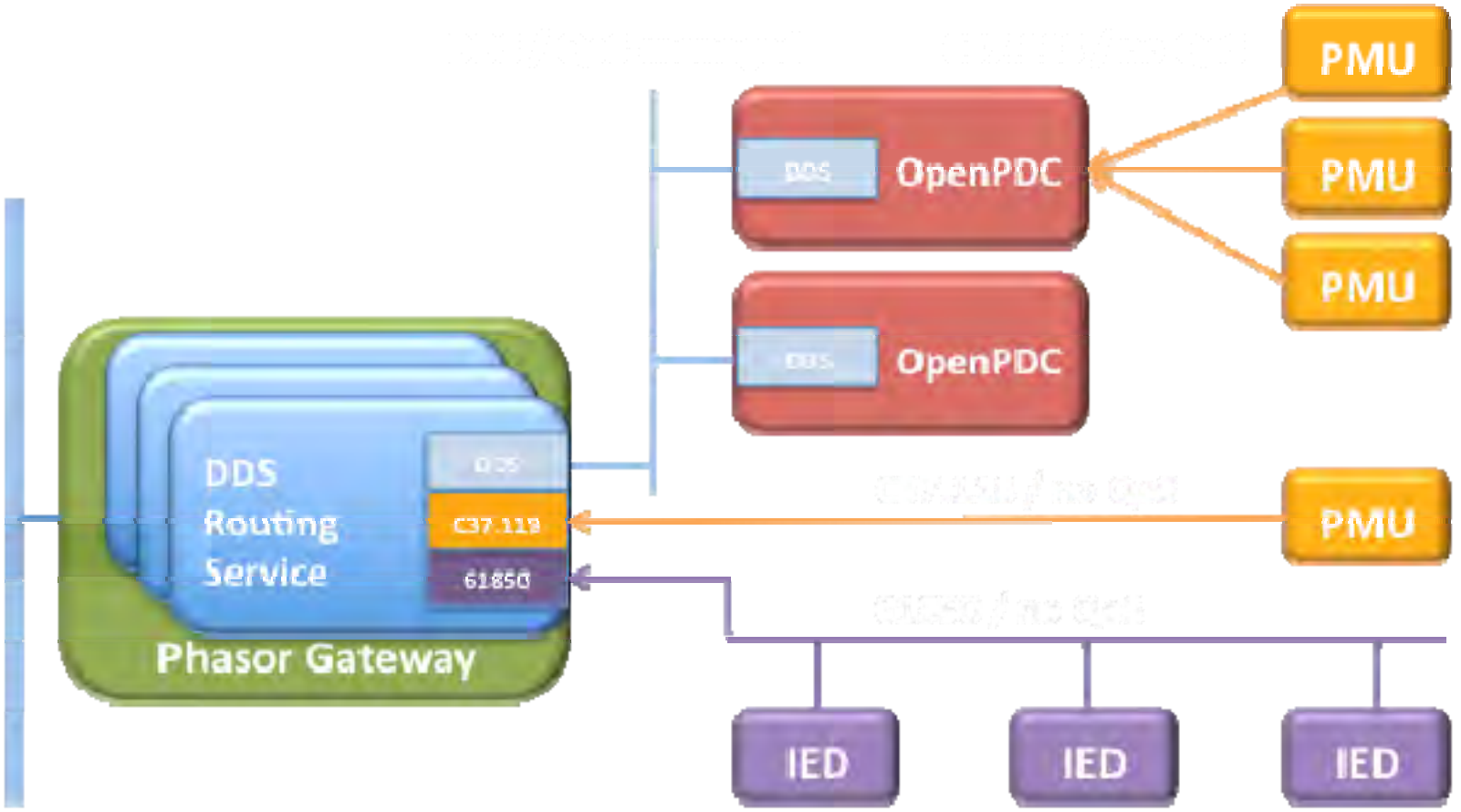
Architecture Vision



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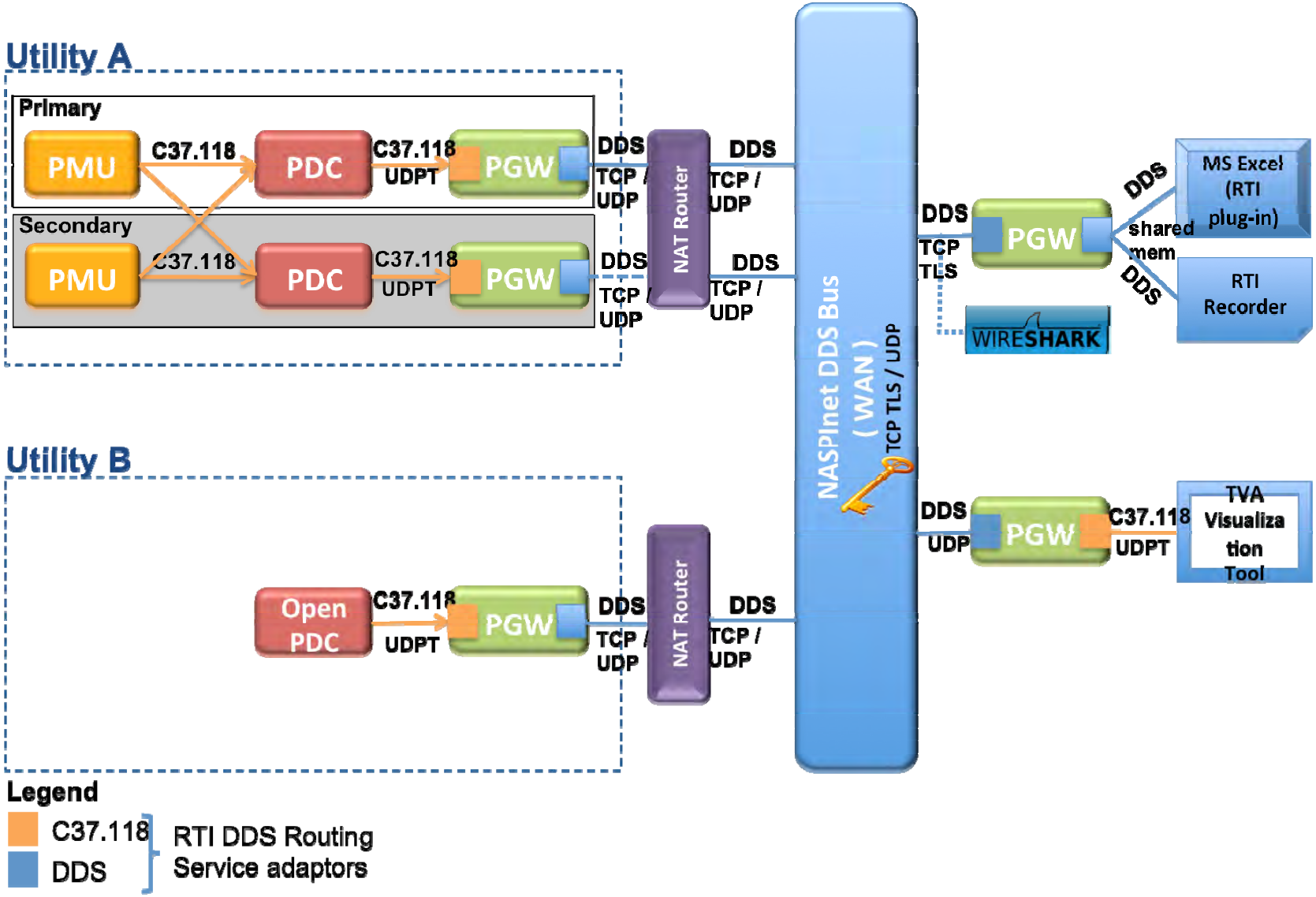
NASPI Use Case Demo



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Austin Use Case Demo (Feb): Demonstrated Requirements

- Interoperability between different protocols
  - C37118 and Data Distribution Service (DDS)
  - Enabling Capability: Routing Service adapters

- High availability and fault tolerance
  - Two redundant (PMU, PDC, RS) configurations
  - Enabling Capability:
    - DDS QoSs (OWNERSHIP, DESTINATION_ORDER, LIVELINESS)
    - DDS Monitoring

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Vancouver Use Case Demo: Demonstrated Requirements

- Interoperability between different protocols
  - GPA OpenPDC intregration
- High availability and fault tolerance
- WAN Traversal
  - Enabling capability:
    - Pluggable TCP transport
- Monitoring and Situation Awareness
  - Monitored PG status: Throughput, CPU usage, etc.
  - Enabling Capability: Routing Service monitoring & DDS monitoring features.

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Vancouver Use Case Demo: Demonstrated Requirements

- Auditing
  - Storage of synchrophasor data into persistent storage
  - Enabling Capability: RTI Recorder service
- Data Classes
  - Slow subscribers can receive samples at a lower rate
  - Enabling capability: DDS QoSs (TIME_BASED_FILTER)
- Security
  - Secure communication channel between RSs (Confidentiality, Integrity)
  - Enabling capability: Secure TCP transport

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New Features

- Interoperability between different protocols
  - DDS adapter inside openPDC
  - RTI Routing Service adapter for protocols supported by openPDC
- Security
  - Access Control Mechanism
  - Enabling capability: RTI Routing Service

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Why DDS for the Grid?

- Proven: Built on field-proven technology
- Flexible: Handles all use cases
- Fast: Sub-millisecond deterministic delivery
- Easy: Proven multi-point integration
- Open: Internationally-standard API, wire protocol
- Reliable: N-way redundancy support
- Scalable: Reliable multicast & partionable
- Plug and Play: Automatic discovery
- Interoperable
  - Plug-ins support C37.118, 61850, other protocols
  - Also across operating systems, languages, network transports, chip architectures, vendors
- Secure: Implements modern security, authentication, access control and intrusion detection (in progress)

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